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Activated Sludge with Powdered Activated Carbon Treatment of a Dyes and Pigments Processing Wastewater

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16. ABSTRACT
This paper discusses completed efforts in the treatment of dyes and pigments processing wastewater utilizing the activated sludge process (ASP) enhanced with powdered activated carbon (PAC). The independent variables of the study were solids retention time (SRT) and PAC dosage. Three SRTs were studies (~4 days, ~ 8 days, ~20 days) with a control system (no PAC) and experimental system (PAC added) operated in parallel.PAC dosages of 70, 130, 290, 1000 and 1800 mg/L were evaluated, although not at all SRTs studied. Gross organics, color, metals and toxicity reduction data are presented. Development of biokinetic constants from the control systems' gross organics data are also presented. The addition of PAC to the ASP did enhance the removal of organics and color and showed a reduction in toxicity of the final effluent to fathead minnow and Daphnia magna as compared to the control systems.

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ACTIVATED SLUDGE WITH POWDERED ACTIVATED CARBON TREATMENT OF A DYES AND PIGMENTS PROCESSING WASTEWATER

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Activated Sludge with Powdered Activated Carbon Treatment of a Dyes and Pigments Processing Wastewater

Introduction

For the past thirteen years the United States Environmental Protection Agency's (EPA) Office of Research and Development (ORD) has had a major program on the development and demonstration of more cost-effective methods of controlling pollution from industrial wastewaters. Initially this program was concerned with the control of conventional pollutants such as suspended solids (SS), oil and grease, and biochemical oxygen demand (BOD). During the past five years the emphasis has changed from the control of conventional pollutants to the control of specific toxic pollutants and toxicity as measured by aquatic bioassays. The overall objective of this program has been the generation of data which would assist EPA in the development of technology-based industrial effluent limitations guidelines and standards.

Since 1975, the Industrial Environmental Research Laboratory in Cincinnati, Ohio (IERL-Ci) has had the responsibility for conducting both in-house and extramural studies on a number of major industrial categories including: food processing, pulp and paper production, leather tanning and finishing, organic and inorganic chemicals production, as well as nonferrous metals processing. One of the in-house studies, initiated in July 1981, was designed to evaluate the treatability of a dyes and pigments processing wastewater using an activated sludge (AS) process both with and without the addition of powdered activated carbon (PAC).

Materials and Methods

This study was conducted at EPA's Test and Evaluation (T&E) Facility in Cincinnati, Ohio. Four continuous-flow activated sludge (AS) pilot plants operated in parallel were used from July 1981 to January 1983. A

detailed description of these pilot plants was outlined in a previous paper (1).

The wastewater used as a feed for this study was collected from a municipal sewer downstream from the discharge of a dyes and pigments processing plant. The industrial wastewater was neutralized with lime and passed through a lagoon prior to discharge to the municipal sewer. Although the industrial discharge is diluted with domestic sewage, sampling above and below the discharge indicated that about 95 percent of the chemical oxygen demand (COD) in the combined wastewater at the collection site could be attributed to the industrial discharge. Approximately every two weeks, 19 m^3 (5000 gallon) of wastewater was pumped from a manhole into a tank truck and transported to the T&E Facility. The wastewater was transferred to a vented 19 m^3 storage tank which was provided with continuous recirculation to assure good mixing. The wastewater was often deficient in nitrogen so urea was added to the storage tank to increase the nitrogen content such that the five-day biochemical oxygen demand (BOD_5) to nitrogen (N) ratio was at least 20 to 1. Adequate phosphorus was available in the waste and no additions were necessary.

All chemical analyses were performed by the University of Cincinnati following an EPA approved quality assurance/quality control plan (2). The analyses were performed in accordance with Standard Methods (3) and/or EPA Approved Methods (4). Sampling of the AS pilot plants consisted of 24-hour composites for the raw waste, primary effluent and secondary effluent. Grab samples were taken from the aeration basin for solids analyses, pH, dissolved oxygen (DO), sludge volume index (SVI) and dissolved oxygen uptake rate (DOUR).

Weekly grab samples of the raw waste and the secondary effluent were also taken for bioassay testing in accordance with "Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms" (5) or "Beckman Microtox™ System Operating Manual" (6)*. Three types of bioassay tests were conducted by EPA: an unaerated, static, acute, fathead minnow 96 hour LC50; a Daphnia magna, unaerated, static, acute 48 hour EC50; and a bacterial assay, Microtox™, 15 minute EC50. The LC50 is the percentage of the sample (raw waste or secondary effluent) after dilution with a high-quality water that results in the death of 50 percent of the fathead minnows in 96 hours. The EC50 is the percentage of the sample that immobilized 50 percent of the Daphnia after 48 hours or resulted in a 50 percent inhibition on light production in the Microtox™ test.

Experimental Program

The following table summarizes the experimental conditions of this study:

Table 1. SUMMARY OF OPERATING CONDITIONS

Segment	Phase	Targeted SRT (days)	PAC Dosage (mg/l of inf. flow)
I	1	8	0
		8	130
	2	8	0
		8	1800
	3	8	0
		8	1000
II	Low SRT	4	0
		4	300
	High SRT	20	0
		20	70

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

During Segment I, all systems were operated in parallel at a targeted solids retention time (SRT) of eight days while three PAC dosages were investigated corresponding to Phases 1, 2 and 3. For each phase, a control AS and a AS/PAC system were operated.

Prior to the start of Segment II, the AS pilot plants were restarted with fresh seed (return activated sludge) obtained from a 130 l/min pilot plant receiving screened raw wastewater from the Cincinnati Metropolitan Sanitation District's Mill Creek Sewage Treatment Plant (same as Segment I). During Segment II, all systems were operated in parallel with different SRTs and PAC dosages which resulted in approximately the same PAC concentration in the aeration basin as that estimated for Phase 1, Segment I.

All data reported herein are from systems operated in the complete-mix hydraulic design mode only, although during Segment I, three runs with plug-flow units were made with the results previously reported (1).

RESULTS AND DISCUSSION

Raw Wastewater

In general, the feed to the pilot plants could be characterized as a highly variable, highly colored wastewater which was typically high in organics and metals. There were significant differences in the wastewater characteristics during the two Segments of this study and these are summarized in Tables 2 and 3. Although the BOD_5 values were similar during the two Segments, the COD and color content of the wastewater was significantly higher during Segment I. There were also significant differences in the individual metal concentrations between the two Segments.

Table 2. SEGMENT 1 RAW WASTEWATER CHARACTERIZATION

PARAMETER*	MAXIMUM	MINIMUM	MEDIAN	MEAN	STANDARD DEVIATION
BOD_5	1900	700	1110	960	380
COD	2840	2280	2600	2590	160
TOC	1080	630	870	860	150
TSS	1270	550	850	730	290
Color**	9910	1240	4250	2850	3040
Alkalinity†	1610	530	950	890	290
TKN as N	300	45	150	140	83
NH_3 as N	160	22	82	76	55
Total Phos. as P	53	30	39	38	9
Total Chromium	4.0	2.2	3.5	3.2	0.9
Total Lead	13.6	6.4	7.0	9.0	4.0
Total Copper	2.4	0.9	1.1	1.5	0.8
Total Zinc	12.2	1.6	1.9	5.2	6.0

* All values expressed as mg/l, except as noted.

** Values expressed as American Dye Manufacturing Institute (ADMI) color units.

† Values expressed as mg/l $CaCO_3$

Table 3. SEGMENT II RAW WASTEWATER CHARACTERIZATION

PARAMETER*	MAXIMUM	MINIMUM	MEDIAN	MEAN	STANDARD DEVIATION
BOD_5	1190	460	790	780	230
COD	1870	1260	1540	1550	190
TOC	770	420	620	620	99
TSS	1580	290	710	610	390
Color**	2820	1070	1520	1410	480
Alkalinity†	1080	360	670	600	200
TKN as N	85	62	73	72	8
NH_3 as N	55	37	44	41	6
Total Phos.as P	72	6	39	42	24
Total Chromium	13.9	0.58	8.3	9.2	3.8
Total Lead	4.9	1.5	2.9	2.4	1.2
Total Copper	1.4	0.23	0.78	0.81	0.3
Total Zinc	8.5	0.27	1.1	0.47	2.3

* All values expressed as mg/1, except as noted.

** Values expressed as ADMI Units

† Values expressed as mg/1 $CaCO_3$

Operational Data

Throughout both Segments of this study the influent feed rate was maintained at about 173 liters/day (120 ml/min) which resulted in a 1.2 day hydraulic detention time in the aeration basin (based upon influent rate only). The activated sludge return rate from the secondary clarifier to the aeration basin was also about 173 liters/day also (range 170-210 l/day). The rate of wasting of the mixed liquor was varied during the experimental runs to obtain the desired SRTs. The dissolved oxygen concentration in the aeration basin was maintained at or above 2 mg/l, and the pH and temperature ranges for the basins were 7.0 to 8.5 and 22 to 27 ^{o}C, respectively.

Following startup of the AS pilot plants and after each change in the operational conditions, the units were operated for at least three times the SRT to assure they were operating as close to steady-state as possible with the varying influent characteristics. Once steady-state had been reached, the detailed sampling and analytical program was initiated. The following discussion and summary tables cover only the "steady-state" conditions for the AS and the AS/PAC units when operated in the complete-mix mode.

Table 4 presents a summary of the key operational data for the AS pilot plants. As stated earlier, an attempt was made to operate the units at SRTs 4, 8 and 20 days. As shown in Table 4 some deviations were experienced. Likewise, the targeted aeration basin PAC concentration of 1000 mg/l for Phase I and for Segment II was not achieved. Lower MLVSS to MLTSS ratios were experienced during Phase I and II due to high influent inert solids.

The addition of PAC to the aeration basin presented a problem in trying to determine both the PAC concentration and the MLVSS concentration in the aeration basin. The analytical methods attempted during Segment I were unsuccessful and a PAC concentration in the aeration basin was calculated

Table 4. SUMMARY OF PROCESS OPERATIONS

	PAC dose mg/l	SRT days	MLTSS mg/l	Aeration Basin PAC mg/l	MLVSS mg/l	Effluent TSS mg/l	F/M† day^{-1}	SVI ml/g
Segment I								
Phase 1								
AS	0	7	1,900	0	790	85	0.8	53
AS/PAC	130	7	2,800	850	NA*	80	NA	41
Phase 2								
AS	0	8	2,300	0	1,130	93	0.7	86
AS/PAC	1,800	9	17,500	14,000	NA	78	NA	12
Phase 3								
AS	0	7	2,000	0	1,280	76	0.7	100
AS/PAC	1,000	10	12,900	8,200	NA	29	NA	39
Segment II								
Low SRT								
AS	0	4	1,090	0	720	71	0.8	54
AS/PAC	290	4	2,950	1,300	1,130	43	0.5	56
High SRT								
AS	0	16	3,100	0	2,250	91	0.3	67
AS/PAC	68	19	4,660	1,100	2,550	77	0.2	40

* Not available, could not determine MLVSS

† mg BOD per mg MLVSS-day

based upon the dosed concentration, the hydraulic detention time and the SRT. During Segment II, the PAC and the MLVSS concentrations were determined using the University of Cincinnati's variation of "Zimpro's "Modified Nitric Acid Digestion Method for Determination of Carbon Content in Sludge" (7).

Organics Removal

Table 5 presents a summary of BOD_5, COD, TOC and color removal efficiencies for the activated sludge process. Each set of runs consists of a control (no PAC) and an experimental system (with PAC) with the SRT held relatively constant. It should be emphasized that the effluent concentrations of BOD_5, COD and TOC as well as the effluent color in ADMI units are all soluble measurements (after filtration through 0.45 micron filter).

As shown in Table 5, the BOD removal was very good for both the control (AS) and the experimental systems (AS/PAC) for all five sets of runs with the daily soluble effluent BOD_5 rarely exceeding 30 mg/l. Although the PAC system experienced lower average soluble effluent BOD_5 in four out of the five pairs of runs the differences may not have been statistically significant in all cases. For the control units the one with the highest SRT (16 days) did produce the lowest soluble effluent BOD_5 but the 4-day SRT unit produced an effluent lower than the runs with an SRT of 7-8 days. This was probably a result of the significant variability in the raw wastewater as discussed earlier. For Segment I it did appear that the additional BOD_5 removal by the experimental units was related to the PAC dosage.

The percentage removals for COD, TOC and color were lower than those for BOD in all runs but the experimental units with PAC addition did increase the removal of these three parameters in essentially all cases over the control units. This was more readily apparent in Table 6 which lists the amount of organics removed by the PAC addition as well as the PAC dose, SRT

Table 5. SUMMARY OF BOD, COD, TOC AND COLOR REMOVAL*

		BOD_5			COD			TOC			Color		
	PAC Dose mg/l	Primary Effluent	Soluble Effluent	Removal %	Primary Effluent	Soluble Effluent	Removal %	Primary Effluent	Soluble Effluent	Removal %	Influent	Effluent	Removal %
Segment I													
Phase 1													
AS	0	880	22	97	1930	690	64	730	300	59	4030	3590	11
AS/PAC	130	880	13	99	1930	580	70	720	280	61	4030	3100	23
Phase 2													
AS	0	920	21	98	1730	430	75	790	310	61	940	1020	-
AS/PAC	1800	930	3	>99	1770	65	96	780	140	82	940	40	96
Phase 3													
AS	0	970	15	98	1220	320	74	640	230	64	1340	890	34
AS/PAC	1000	990	2	>99	1300	50	96	630	80	87	1340	30	98
Segment II													
Low SRT													
AS	0	660	10	98	1180	510	57	450	200	56	1410	1540	-
AS/PAC	290	640	8	99	1180	340	71	470	140	70	1410	1190	16
High SRT													
AS	0	670	6	99	1170	490	58	470	190	60	1410	1690	-
AS/PAC	68	630	7	99	1180	440	63	450	170	62	1410	1510	-

*Influent and effluent concentrations in mg/l except color in ADMI units

the estimated aeration basin PAC concentration. The amount of organics removed by the PAC was calculated as follows:

From Table 5 for AS/PAC run with PAC dose of 68 mg/l

AS effluent COD = 490 mg/l

AS/PAC effluent COD = 440 mg/l

assumed COD removed by PAC = 490-440 = 50 mg/l

$$\% \text{ COD removed} = \frac{AS - AS/PAC}{AS} = \frac{490 - 440}{490} = 10\%$$

Table 6. ORGANICS REMOVED BY THE PAC

PAC Dose mg/l	SRT days	AERATION Basin PAC - mg/l	Δ SCOD*	Removed	Δ SOC†	Removed	Δ Color	Removed
			mg/l	%	mg/l	%	ADMI Units	%
68	19	1100	50	10	20	10	100	11
130	7	850	110	16	20	7	490	14
290	4	1300	170	33	60	30	350	23
1000	10	8200	270	84	150	65	860	97
1800	9	14000	365	85	170	55	980	96

* Soluble COD
† Soluble organic carbon

The incremental removal of organics by PAC is given both in mg/l or ADMI units, and in percent. This was done because neither of these ways alone will provide an absolute measure of the effect of the PAC addition due to the planned variability in the SRT and the large (unplanned) variability in the raw waste characteristics. For all three organic measurements, the incremental removal by the experimental unit over the control unit increased with increasing PAC feed concentration at least until the adsorbable fraction was nearly completely removed. Approximately 15 percent of the effluent

SCOD from the control unit, 50 percent of the SOC and 4 percent of the soluble color was not readily adsorbed.

Even though the SRT varied from 4-19 days for the AS/PAC runs it was of interest to calculate the incremental amount of organics removed per unit weight of carbon fed to the aeration basin based on the differences reported in Table 6. This was done for SCOD with the following results:

PAC Dose mg/l	mg SCOD Removed per mg Carbon Dosed
68	0.74
130	0.85
290	0.59
1000	0.27
1800	0.20

These SCOD removals per unit weight of carbon appeared high and indicated that there may have been some biological degradation of the organics adsorbed by the carbon (partial regeneration), thus allowing additional adsorption of organics. In an attempt to validate this assumption the above data were plotted according to the Freundlich equation:

$$\frac{X}{M} = K C_f^{\frac{1}{n}}$$

where:

$\frac{X}{M}$ = the amount of SCOD removed per unit weight of carbon

n,K = constants

C_f = the amount of SCOD in final effluent for each AS/PAC run

This plot is shown on Figure 1 along with three other lines which were obtained from batch jar test runs on the effluents from the control AS unit at several times throughout this study. A comparison of the line from the AS/PAC data with the three isotherms from the jar tests does suggest that the SCOD removed by the carbon in the AS/PAC runs was higher than expected based, at least on these three isotherms. The equation describing the apparent SCOD removal by the carbon in the AS/PAC units is:

$$\frac{X}{M} = (0.026)C_f^{(0.56)} \qquad (1)$$

where:

$\frac{X}{M}$ = SCOD removed per unit of carbon, mg/mg

C_f = Effluent SCOD, mg/l

This equation provides a good fit of the data even though the SRT varied from 4 to 19 days, the influent COD varied from 1170 to 1930 mg/l and the control AS effluent SCOD varied from 320 to 690 mg/l.

A similar calculation was done for color removal and the data points for the five sets of runs are shown on Figure 2. A line of best fit was calculated for four of the five data points in this case; the fifth one was excluded since the effluent color for the control AS unit was 3590 ADMI units and this was more than twice that of any other run. Batch jar test isotherms were also conducted for color removal. They are not shown on the Figure since they were very similar to the line shown. The equation of the line is:

$$\frac{X}{M} = (0.36)\, C_f^{(0.18)} \qquad (2)$$

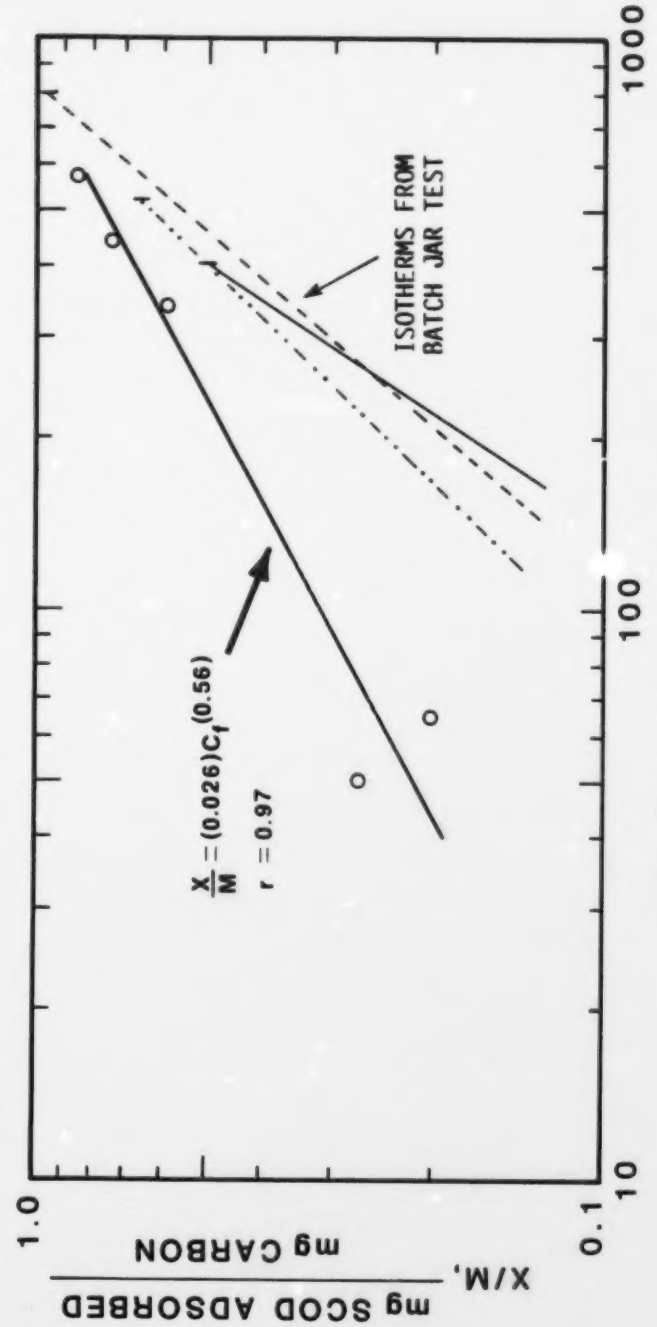

Figure 1. Carbon Adsorption Isotherm for SCOD

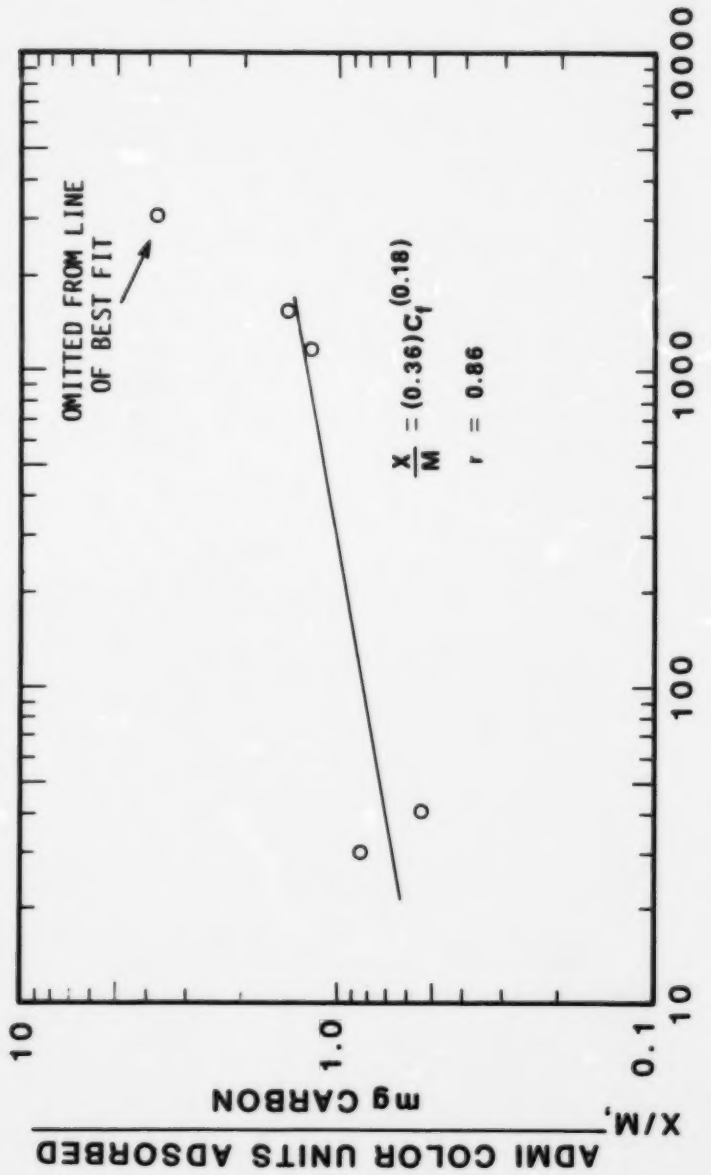

Figure 2. Carbon Adsorption Isotherm for Color

where:

$\frac{X}{M}$ = ADMI color units removed per mg of carbon

C_f = Effluent color, ADMI units

This formula describes the color removal when the influent to the AS systems was in the range of 940 to 1410 ADMI units and when the effluent color for the control AS units was in the range of 890 to 1690 ADMI units.

In order to describe the effects of varying influent concentration, a model for substrate utilizaton suggested by the work of Grau, et al., [8] was used to fit the BOD data from the control AS runs. Grau's equations for substrate utilization, when inserted into a mass balance for substrate yields:

$$K_e' S_e = \frac{S_i (S_i - S_e)}{X\theta} \qquad (3)$$

where:

K_e' = rate constant; 1/time

S_e = soluble effluent substrate concentration; mass/volume

S_i = influent substrate concentration; mass/volume

X = concentration of microorganisms; mass/volume

θ = hydraulic detention time; time, and

the soluble effluent substrate concentration may be described by;

$$S_e = \frac{S_i (1 + \theta_c K_d)}{(\theta_c Y_t K_e')} \qquad (4)$$

where:

θ_c = solids retention time; time

K_d = endogenous decay coefficient; 1/time

Y_t = total yield of microbial mass/mass of substrate removed

Equation 3 was used to determine $K_e' = 19$ and then a form of Equation 4 was used to determine Y_t and K_d as shown on Figure 3. The oxygen demand rate coefficients, a and b, were derived from Figure 4. These constants resulted in the following kinetic equations for this industrial wastewater:

$$S_e = \frac{S_i\ (1 - 0.049\ \theta_c)}{(19)\ (0.55)\ \theta_c}$$

$$S_e = \frac{S_i\ (1 - 0.049\ \theta_c)}{10\ \theta_c}$$

$$O_2 = 0.48\ (C_i - C_e) + (0.02)\ MLSS$$

where:

O_2 = Oxygen required, Kg/day

C_i = Influent BOD, Kg/day

C_e = Soluble effluent BOD, Kg/day

MLSS = Mixed liquor suspended solids under aeration, Kg

Metals Removal

A summary of the data collected on lead and chromium is presented in Table 7. Soluble chromium and soluble lead analyses were also run during Segment I but the filter used to remove the suspended solids was coarser than the 0.45 micron filter used during Segment II, therefore, the results are not included. Analyses were also conducted for copper, nickel and zinc but only lead and chromium are presented since they were present in the largest concentrations and the removal trends were similar to those for the other three metals.

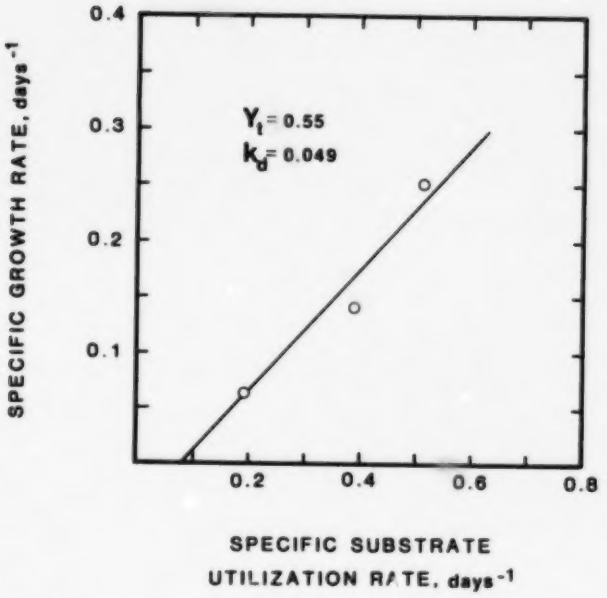

Figure 3. Determination of Yield and Endogenous Respiration Rate Constants

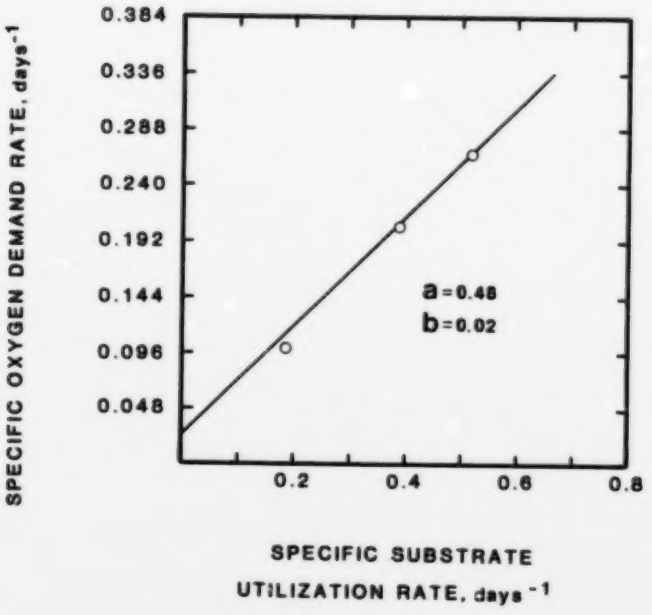

Figure 4. Determination of Oxygen Requirements

Table 7. SUMMARY OF METALS DATA*

		Influent	Primary Effluent	Secondary Effluent	
				AS	AS/PAC
Segment I					
Phase 1	Total Cr	3.2	1.1	0.39	0.32
	Total Pb	9.0	2.0	0.65	0.50
Phase 2	Total Cr	3.2	1.4	0.23	0.33
	Total Pb	7.9	2.3	0.51	0.35
Phase 3	Total Cr	1.6	0.93	0.33	0.21
	Total Pb	2.6	0.94	0.33	0.16
Segment II					
Low SRT	Total Cr	8.4	2.0	0.59	0.30
	Soluble Cr	0.48	0.51	0.43	0.09
	Total Pb	2.6	0.79	0.20	0.20
	Soluble Pb	0.20	0.24	0.18	0.16
High SRT	Total Cr	9.1	2.5	1.2	0.86
	Soluble Cr	0.48	0.51	0.34	0.34
	Total Pb	2.4	0.94	0.30	0.31
	Soluble Pb	0.19	0.23	0.19	0.17

*All concentrations in mg/l

As shown in the Table primary clarification reduced the total lead and chromium concentration by 50 to 75 percent resulting in effluent concentrations ranging from 1 to 2.5 mg/1. The aeration basin and secondary clarifier further reduced the total lead and chromium concentrations an additional 50 to 80 percent. In general, the secondary effluent concentrations for total lead and chromium for the AS/PAC pilot plants were similar to or slightly lower than those for the control units (AS).

There was no removal of soluble lead and chromium by primary clarification and there were no significant differences in removals between the AS and the AS/PAC units with one exception. For the four-day SRT run of Segment II the AS/PAC reduced the soluble chromium to a lower concentration than the AS unit - 0.09 mg/1 vs 0.43 mg/1. Based upon these data and the lack of knowledge concerning what types of products were being produced by the dyes and pigments processing plant, it was not possible to speculate upon why soluble chromium was removed by PAC during this run and not during the parallel run with an SRT of about 15 days even though the carbon dosage was much higher for the 4-day SRT unit -- 290 vs 68 mg/1, respectively.

During each of the runs the sludge from the primary clarifier (WPS) and the waste activated sludge (WAS) was sampled along with the raw wastewater and final effluent for metals analyses so that mass balances could be calculated. This was done to check out the combined errors in sampling and analyses. A typical example for the 4-day SRT run during Segment II yielded the following:

$$(100) \times \frac{(\text{mg/day final effluent}) + (\text{mg/day WAS}) + (\text{mg/day WPS})}{\text{mg/day influent to plant}}$$

	Chromium	Lead
AS	105%	101%
AS/PAC	119%	92%

Based upon these mass balances and the analytical QA/QC program it appears that the overall sampling and analyses for this study provided meaningful results.

Toxicity Reduction

A summary of the acute bioassay results is presented in Table 8 for the weekly grab samples of the raw waste and the secondary effluent throughout this study. The LC50 values for the fathead minnow are the percentage of the influent or effluent (diluted) that killed 50% of the minnows in 96 hours. Likewise, the EC50 values for the Daphnia magna are the percentages that immobilized 50% of the organisms in 48 hours, and for the Microtox™ the percentage that caused a 50% inhibition (affect) on light production in the test. Thus, the higher the LC50 or EC50 number the lower the toxicity and conversely, the lower the number the higher the toxicity.

The bioassay results for all three test organisms show a variability in toxicity for the raw waste similar to the variability discussed earlier for organics. The toxicity of the raw waste to Daphnia magna was similar or greater than to the fathead minnow, with Microtox™ measuring the greatest effect.

Although not specifically measured or tested, the greater toxicity of the raw waste as indicated by the Microtox™ assay may have been caused by a greater sensitivity of the bacteria to dyes and dye intermediates. A number of dyes are, in fact, used as prophylactic treatments in fish culture.

For all pairs of runs the toxicity of the raw waste was significantly reduced for all three test organisms with the percent reduction for Daphnia and the minnow being similar. The percentage reduction as measured by the Microtox™ was greater than for the other two test organisms. In all cases,

TABLE 8. SUMMARY OF ACUTE BIOASSAY TESTS*

	FATHEAD MINNOW 96 hr. LC50			DAPHNIA MAGNA 48 hr. EC50			MICROTOX™ 15 min. EC50		
	Influent	Effluent	Reduction %	Influent	Effluent	Reduction %	Influent	Effluent	Reduction %
Segment I									
Phase I									
AS	6	15	60	5	21	76	0.4	23	98
AS/PAC	6	23	74	5	31	84	0.4	>28	>99
Phase 2									
AS	7	20	65	<2	15	>87	0.6	26	98
AD/PAC	7	>38	>82	<2	24	>92	0.6	>45	>99
Phase 3									
AS	13	34	62	12	47	74	0.9	8	89
AS/PAC	13	>82**	>84	12	>90**	>87	0.9	NAT†	100
Segment II									
Low SRT									
AS	23	59	61	12	49	76	1.4	>40	>96
AS/PAC	23	NAT	100	12	62	81	1.4	NAT	100
High SRT									
AS	23	52	56	12	50	76	1.4	>50	>97
AS/PAC	23	>91	>75	12	54	78	1.4	NAT	100

* All acute toxicity values are in % influent or effluent and are mean values for weekly grab samples

† No Acute Toxicity (NAT), no mortality or less than 50% effect in 100% effluent

** 3 of 4 samples had NAT

the percentage reduction in toxicity by the experimental AS/PAC systems was greater than it was for the control AS systems.

CONCLUSIONS

The following conclusions can be drawn from this eighteen-month study on the treatability of a dyes and pigments processing wastewater using activated sludge pilot plants, with and without the addition of powdered activated carbon to the aeration basin:

1. The activated sludge process (no PAC) reduced the BOD_5 by 97 to 98% (based upon total influent and soluble effluent) at solids retention times ranging from 4 to 16 days.
2. The AS process reduced the COD and TOC (based upon soluble effluent) by 57 to 75% and 56 to 64%, respectively.
3. The AS process removed very little of the color, from 0 to 34%.
4. Addition of powdered activated carbon to the activated sludge process increased the removals of BOD, COD, TOC and color with removal ranges of 99 to >99%, 63 to 96%, 61 to 87%, 0 to 96%, respectively.
5. The additional removal of organics by the powdered carbon was a function of the amount of carbon added.
6. The powdered carbon did not improve the removal of soluble lead and chromium, although it did improve the removal of suspended solids in the secondary clarifier.
7. The activated sludge process removed 50 to 98% of the toxicity as measured by three test organisms, and the addition of powdered carbon increased the removal of toxicity in all cases.

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